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EDITORIAL NOTES.

THE present number completes the sixtieth volume of the GEOLOGICAL MAGAZINE, which was started in 1864, under the actual editorship of Dr. Henry Woodward, although the name of Professor T. Rupert Jones occupied the first place on the title page. The first volume comprises only six numbers: July to December, 1864. It is of interest to find, however, that it includes original papers by three eminent geologists still happily with us, namely, Sir Archibald Geikie, Sir William Boyd Dawkins, and Mr. William Whitaker. There are also brief abstracts of papers published elsewhere by Sir E. Ray Lankester and Bishop G. F. Browne. It would occupy too much space to enumerate all the deceased writers well known to fame whose names also appear in the index of this volume. The typographical form and general appearance of the Magazine are strikingly similar to those still prevailing.

In 1864 the British Association met at Bath under the presidency of Sir Charles Lyell, and the list of papers read in Section C indicates great activity in geological research at that time: the titles alone occupy over two pages, and range over a wide variety of subjects: many of the abstracts are given in the Magazine, an excellent practice which, however, it has been impossible to follow of late owing to the great influx of original matter.

The early history of the Magazine was recently dealt with at some length on the occasion of the death of the first editor, Dr. Henry Woodward, after a reign of 57 years, and it is scarcely necessary to repeat what was then said, but it was felt desirable to call attention briefly to the occurrence of an interesting anniversary.

ORIGINAL ARTICLES.

Further Observations on the Volcanic Geology of East Fife.

By David Balsillie, F.G.S.

(PLATE XX.)

TO the old volcanoes of East Fife Sir Archibald Geikie assigned a Permian age. In the course of a characteristically able series of investigations he discerned that on the shore at Lundin Links one vent had penetrated some of the highest members of the Scottish Coal Measures, whereas at Kennoway another could be seen to have risen through the Millstone Grit. There further appeared to be a general similarity in the lithologic and petrographic characters of the materials of the entire group, thus linking them together, and they seemed to have taken birth after the inception of the tectonic features of the area. Only one simple conclusion emerged from a consideration of these facts, namely, that the vents must be referable to some period of post-Carboniferous time. In support of that opinion he pointed especially to the Largo district, where he thought he could detect a sheet of fragmental volcanic material resting with a distinct unconformability upon the folded and denuded Carboniferous strata, which supposition, of course, could it be confirmed, would render further discussion upon the matter unnecessary. But in the East Fife Memoir it is stated that the sections which might be expected to furnish critical evidence are not clear.

Reared in the old burgh of St. Andrews, where, to the east of the town, some of the volcanic memorials above referred to have been laid bare by the sea, the writer was led in earlier years, mainly through the stimulus of the writings of Sir Archibald Geikie, to devote attention to a study of their various problems, and not least to an ascertainment, if possible, at what period in bygone time volcanic activity had attained a culmination in the area. At first no other conclusion seemed possible than that which had previously been arrived at, viz. that the necks must be, if not clearly post, at all events, certainly, very late Carboniferous; the apparent posteriority of the vents to the folding of the strata among which they occur being the main reason for rejecting any alternative opinion. Recently, however, a new avenue of approach to the age question became available. In a paper dealing with the petrographic characters of the diabase intrusions of the district[1]

[1] D. Balsillie, "Notes on the Doleritic Intrusions of East Fife": Geol. Mag., Vol. LIX, 1922, p. 442.

attention was directed to the striking similarity between the olivine-dolerites and the vent-basalts, and to the possibility of there being some genetic relationship betwixt these differently occurring masses. The belief was put forward that the intrusion of large volumes of igneous rock might perhaps seriously disturb, possibly plicate and fracture, the lower members of a still accumulating sequence, so that volcanic orifices subsequently drilled to the exterior would appear to be, and really would be, posterior to the inauguration of such tectonic features as might be developed in the manner indicated, and one serious difficulty in the way of a Carboniferous age-allocation removed. The olivine-dolerites being assigned to the period of the Upper Limestones, the proposition naturally arose: could it not be that the vents also should be referred to this known epoch of subsurface igneous activity in East Fife? The xenocrysts that occur in the neck basalts proved at first somewhat of an obstacle to their association with the doleritic intrusions. Consideration, however, shows that they are really such as might be expected to separate under favourable conditions from the olivine-dolerite—teschenite magma.

The next helpful reflection, although geologically, perhaps, a crude and unsound one, was that in which it was supposed that the chimneys must be funnel-shaped; probably expanding in their course upwards from depths. Presuming that the necks are not Permian, but Carboniferous, it will be seen that an immediate implication of this is that the horizontal extension of the materials of any one neck, parallel to the bedding planes of the associated sedimentary rocks, should be an expression of the stratigraphical level at which its remains are now found; the maximum extension suddenly occurring at the horizon at which its extruded circumjacent products are still preserved: somewhere, for these East Fife necks, in the Upper Limestone group, if the above inferences are valid. Now, the only part where the Upper Limestones and associated strata occur in the district is in the neighbourhood of Largo: it is precisely here that there is an apparent great spread of ash. Sir Archibald Geikie was of opinion that this ash formed part of a once more extensive unconformable Permian covering.[1] But there is no clear geological reason why such a mantle should have been preserved only in the neighbourhood of Largo. On the other hand, if the age of the vents be Lower Carboniferous, then the explanation of its existence simply as interstratified material will be immediate.

From what has been written, it will be seen that the Largo district becomes of extreme importance in its bearing upon this age question of the East Fife necks. It was, therefore, resolved to put these

[1] See "On the Carboniferous Volcanic Rocks of the Basin of the Firth of Forth": *Trans. Roy. Soc. Edin.*, vol. xxii, 1879. *Ancient Volcanoes of Great Britain*, vol. ii, 1897. "Geology of Eastern Fife": *Mem. Geol. Surv. Scotland*, 1902.

respective theories to the test and ascertain by trenching whether the fragmental material was related to the Carboniferous strata as Sir Archibald Geikie had supposed, or whether it was simply one, or a series, of contemporaneous intercalations. Before breaking ground, however, it was considered advisable to subject the whole district to careful scrutiny, so that the best and most promising site for operations with pick and shovel might be selected. The results of this examination, but recently carried out, have been such as to render the proposed geological dissection unnecessary, and in this paper a brief account is given of what has been observed, and of the conclusions arrived at.

Inland from the shore section to the east of Lower Largo gravelly and granular ash, similar to what can be seen in some of the Elie–St. Monans necks, but perhaps with better bedding, crops out on the grassy bluffs in the immediate neighbourhood of Johnston's Mill. Here the inclination, to the east of the cottage marked on the six-inch map "Carrick Villa", is towards the sea, but rolls over to the north-west in the ravine of Strathairly Burn. Further up the same stream, to the east of Strathairly House, a band of ash, probably 20 feet thick, in the main of fine texture, but including coarser zones and with coaly and shaly partings, can be seen dipping sharply to the south-west. This is succeeded by non-volcanic sediments, such as shales, fireclays, coals, and sandstones, similarly inclined, but the outcrops swinging slightly so as to strike in a more southerly direction. The rocks here visible afford no evidence to indicate otherwise than that the pyroclastic material is a regular intercalation in the stratified series.

Between Johnston's Mill and Viewforth, in a little ravine above the railway, very fine red ash, with included gravelly layers, and regularly overlying black shales, has been exposed. The dip is to the east of north and here again, it may be noted, the association of volcanic and non-volcanic material seems to be of the closest character.

In the course of the Largo Burn, near the foot of the Serpentine Walk, a thick zone of ash comes to the surface resting over sandstones and shales with plant remains. There is likewise, here, a complete absence of evidence such as might indicate discordance, and at this exposure one has considerable confidence in declaring immediately for the contemporaneous nature of the volcanic material. But the best and clearest section in the whole area, and that which must remove any remaining doubt as to the relationships existing in this district between these pyroclastic accumulations and their contiguous members, is that further up the channel of the same stream, within the grounds of Largo House, and only a few yards to the south-west of the Commercial Hotel at the Kirkton of Largo. Here, in the east bank of the burn, there emerges to view a vertical thickness of perhaps 17 feet of strata in which the sequence of materials is beautifully shown.

Layers of coarser and finer ash alternate with thin coaly, fissile, and tenacious shaly bands in the most intimate fashion; the whole bringing vividly to the mind a history of intermittent volcanic action. Immediately, also, under the north gable of the lodge, at the Eagle Gates, a similar sequence can be seen. These strata, ashes and associated sediments, dip to the east, forming the western limb of a synclinal trough or centroclinal, whose centre is perhaps somewhere in the neighbourhood of Buckthorns to the south-east of the Kirkton of Largo. The true intercalary relationship of these Largo ashes is thus clearly demonstrated, and in addition the synclinal structure of the Strathairly Coalfield referred to by David Landale in his classical report[1] is confirmed.

A short distance to the north of the section in the Largo Burn, just mentioned, gravelly and granular ash with a south-easterly dip has been laid bare on the roadside just under the Parish Church, while to the north-east of the cemetery along the slopes of a wooded bank there is exposed a similarly inclined association of shales and pyroclastic material.

That lavas also were erupted during the course of the volcanic history at this part is perhaps evidenced by the rocks exposed at two localities. The first of these can be seen at the cross-roads about a third of a mile to the south-east of Pitcruvie Castle, where a much-decomposed cellular igneous rock is overlain by sandstone. It is possibly this same, or probably another, effusive rock which has been laid bare a short distance to the south-east of Baldastard. Here, a small stream running south-east has trenched through the drift into the underlying rocks. The latter in the upper part of the cut are mainly sandy, but towards the base include an intercalated volcanic zone, consisting of an intensely vesicular compact basalt with over and underlying ash. A few yards to the west of this locality at a point marked on the six-inch map as "rises", a somewhat coarse agglomerate is exposed: this, perhaps, may be part of the material of another neck. Microscopically, the Baldastard lava proves to be a porphyritic olivine-basalt, although containing now no unaltered ferro-magnesian constituent. It recalls in some of its characters the comparatively fresh dolerite on the roadside at Blindwells.

The stratigraphic horizon of these pyroclastic and associated materials in the neighbourhood of Largo can be ascertained with reasonable accuracy. Apparently below the main mass of the series of volcanic discharges, a sequence of sandstones, shales, etc., crops out, over a part of the shore, between the fault which brings down the Red Beds of the Coal Measures, and Viewforth. These were regarded by Mr. Kirkby as including a horizon somewhere near the Index Limestone. As has just been said, these strata lie beneath the principal development of volcanic material; but that volcanic

[1] *Prize-Essays and Transactions of the Highland and Agricultural Society of Scotland*, vol. xi, 1837, p. 279.

activity actually obtained in East Fife before this period is perhaps indicated by some sandy tuffs which are exposed on the shore on the west side of Chapel Ness, Earlsferry: these probably stand at a high level in the Edge Coal Group. It may be stated that Mr. David Bowman, of Lundin Links, who has conducted an extensive series of boring investigations over a large part of the Largo district, entirely confirms the conclusion that the tuffs and agglomerates are resting above the Index Limestone. He generously related that, in a sinking at the Serpentine Walk, he struck a calcareous band which he believed to be the Index Limestone, and that his journal of the strata above included several entries of "whin ash". Mr. Bowman was further able to comment upon the remarkable variations in character of the ash zones when traced from place to place. But rapid lateral change among such volcanic accumulations is just what might be expected, and indeed here can be readily inferred from an examination of the available exposures.

As affording additional evidence of the prevalence of volcanic action in Fifeshire at some period subsequent to the deposition of the Index Limestone, reference may be made to the well-known section at Aithernie Castle, north of Leven. Here, a picturesque gorge has been cut through strata lying below a limestone, which has been regarded by the Officers of the Geological Survey as the Gair or Calmy seam. The rocks exposed in the ravine include a thick zone of ash with an intercalated compact blue or black basalt. The character of the ash, in large part of very fine texture and deep red in colour, recalls much of that in the Largo area. It is the opinion of the writer that the Largo volcanics are on the same horizon as this Aithernie "trap". Slides prepared from the Aithernie lava show this to be a highly basic microcrystalline basalt. The rock has been reported upon by Dr. Flett, and the only point of interest that it seems possible to add to his description is the fact that sometimes the mass contains segregations of a purplish pyroxene with strong dispersion. Pyroxene of this character is abundant in the neck rocks of East Fife, but it must be stated that the lava is not a monchiquite.

From what has been said it will be abundantly clear that an examination of the evidence at present available in the Largo district does not confirm the existence of an unconformable sheet of ash: *the materials which were supposed to belong to such mantle are demonstrably interstratified.* The consequences of this discovery are considerable. One of the most important is that the agglomerates and accompanying basalts of the cone of Largo Law, unless these be dissociated from the thick ash sheets close at hand, which seems unreasonable, can no longer be regarded as of Permian age. Further, as the intrusions that cut through the materials of the hill are distinctly alkaline in character, and differ in no essential particular from any of the other neck-basalts of the district,

the conclusion that the vents of East Fife must necessarily be Permian seems no longer to be tenable.

The microscopic characters of the basalts of the vents were described twenty years ago by Professor Seymour and Dr. Flett when, however, their analcitic nature if discerned was not specially emphasized. More recently their petrography has been reviewed by Mrs. Wallace in an interesting paper,[1] and further points of importance added. Most of these rocks are dense, sharp-fracturing, sometimes pitchstone-like masses, very homogeneous to the naked eye, but often carrying large xenocrysts of felspar, biotite, hornblende, etc. Microscopically, they show, as a rule, in sections of fresh material, porphyritic crystals of olivine and monoclinic pyroxene in a ground that includes a second generation of the latter mineral in small idiomorphic prisms, magnetite, felspar, never quite absent but not often abundant, hexagonal plates, shreds, and flakes of biotite, probably hornblende, analcite, and nepheline. Glass, too, brown in colour, and often full of incipient crystalline growths is of frequent occurrence. Occasionally the sections afford beautiful representations of monchiquite, but the masses microscopically are not uniform, the content of felspar, especially, increasing or diminishing rapidly from place to place. As typical members of the series, may be cited the mass at Chapel Ness, west from Elie, and that intrusive in a neck at the west end of Ladeddie Hill, 5 miles west from St. Andrews, one of the freshest and most interesting. Sometimes the rocks are crowded with ocelli or irregular spaces filled with analcite, and having crystals of pyroxene growing out into the centre from the periphery. Again, irregular strings and patches of analcite may be found full of feathery growths of felspar and shreds of biotite. The latter character, reminding one strongly of what can sometimes be seen in the teschenite of Spalefield, is well displayed in the mass fronting the sea at Kittocks Den, to the east of Kinkell Ness. The green-coloured pyroxene referred to by Mrs. Wallace as chrome-diopside occurs as fine segregations in the basalt intrusive in the ash of the third vent east of the "Rock and Spindle".[2]

It was upon a basis of the above characters, or some of them, that Mr. Tyrrell came to the conclusion that the East Fife necks should be allocated to post-Carboniferous time, in this opinion following Sir Archibald Geikie, whose argument, however, was not one founded upon petrography. Thus in a recent paper[3] on the "Classification and Age of the Analcite-bearing Igneous Rocks of Scotland", Mr. Tyrrell writes: "The analcite-bearing rocks are concentrated in four main areas: Fife and the Lothians; the Glasgow district; Ayrshire; and the West Coast from the

[1] "Notes on the Petrology of the Agglomerates and Hypabyssal Intrusions between Largo and St. Monans": *Trans. Edin. Geol. Soc.*, vol. x, p. 348.

[2] See Mem. on Geology of East Fife.

[3] GEOL. MAG., Vol. LX, 1923, p. 249.

Clyde region up to the Outer Hebrides. In the first three of these areas the age of most of the analcitic igneous rocks is Late Carboniferous or Permian; in the last-named area they are probably connected with Cainozoic volcanic activity. Further, the East Fife necks are in all respects identical with the Permian vents of Ayrshire, and carry small intrusions of basic analcite- or nepheline-bearing rocks." Mrs. Wallace likewise inclined to the view that "they belong probably to the same epoch as the volcanic rocks of Central Ayrshire".[1] But it must surely be quite wrong to conclude that when alkaline or analcitic igneous rocks are found in East Central Scotland they must necessarily be assignable to the same period as other corresponding masses in the West whose age is ascertainably later. Thus, in East Lothian there are basalts, analcite-basalts, and trachydolerites, all petrographically closely related to one another. It would be a serious discountenance of the evidence to consider these as of any but pre-Millstone Grit age. One of the most interesting and thoroughly alkaline members of the series, the kulaite of Blaikie Heugh, a rock containing plentiful analcite and apparently former abundant nepheline, is regarded by Mr. Bailey as a lava.[2] From the shore also, a mile east of Dunbar, Dr. Clough[3] has described a rock, which, while having the field relations of a lava, microscopically has affinities with the monchiquites. Analcite, too, and probably nepheline are not infrequent ingredients of the Lower Carboniferous igneous products of the Burntisland district.

As thus presenting itself to the writer, the history of these East Fife necks does not seem to have been one that fell within the range of Permian time. The field evidence of the Largo district, the petrographic evidence linking the vents together, and the palæontology as far as this is available,[4] all direct us back to the confines of the Lower Carboniferous. That there were abundant volcanic discharges in the Largo district in Carboniferous Limestone times is unquestionably proved by the stream sections and natural exposures of that area. It may be safely presumed that whatever adjustments in subterranean economy were then in progress, with accompanying superficial manifestation, they were not restricted to this particular neighbourhood, but affected a more extended belt of territory. That the agglomerate-filled pipes, therefore, of the eastern part of the county represent merely the

[1] Loc. cit., p. 349.

[2] "The Geology of East Lothian": *Mem. Geol. Surv. Scotland*, p. 125.

[3] Ibid., p. 87.

[4] Attention has formerly been directed to the fish teeth in the basalt of the "Rock and Spindle". Either these are derived fossils or they have been directly engulfed by the liquid rock. The fact that they are generally exomorphically entire, and without attached matrix, seems to suggest that the latter explanation is the correct one. In reference to the wood fragments present in many of the tuffs these may have come from the disruption of beds of decaying vegetation lying at or near the surface in Carboniferous times.

LARGO LAW, FIFESHIRE, AN ASH-FILLED VOLCANIC NECK OF LOWER CARBONIFEROUS AGE.

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one-time companions of Largo Law, seems more than likely. Only the tap roots—to resort to botanical terminology—of most of these old volcanoes now remain to us. In the Calciferous Sandstone series we get cross sections of comparatively low levels of the chimneys, but as we ascend to higher horizons we discern more of the parts that one usually thinks of as occurring above ground. At the Kincraig neck, for example, which penetrates strata just below the Index Limestone, we still see the actual base of the former crater with its fan-shaped display of basaltic columns. Above the Index Limestone occurs Largo Law, a portion of the original cone still surviving, and some of the superficial sheets of detritus and extruded lavas still intact. The degraded surface of the country is as an inclined plane that has cut athwart the original stratigraphic sequence and the associated volcanic orifices. In this way we have been permitted to examine the channels of egress over a considerable portion of their vertical extent. Would that we could but ascertain the nature of the phenomena at deeper levels.

Passing further up the geological record to Millstone Grit and Coal Measure time, we note in East Fife a comparative, but not entire, absence of the memorials of vulcanicity. The Millstone Grit at Kennoway has been penetrated by one vent, and a group of strata on the shore at Lundin Links, regarded as belonging to the Red Beds of the Coal Measures, by another. There is, however, no very satisfactory evidence to show that these are members of the foregoing series of necks, and the probability is that they represent sporadic recrudescences of activity at later periods. Apparently, towards the close of Carboniferous times, the principal igneous focus had been transferred to the West of Scotland.

It is fully anticipated that the above conclusions may for some time not be viewed with favour; a stumbling block to their acceptance being always the fact that many of the vents seem to be distinctly later than the faulting. But it should be borne in mind that igneous intrusion may seriously disorder the members of a sedimentary sequence, dissevering and displacing the strata. Faultings, also, might originate in this way; at all events that is what is conceived in explanation of the troublesome dispositions just indicated. But it would be strange indeed if we should deny the possibility of fracturing and bodily shifting by volcanic forces themselves. In this connexion it is interesting to refer to what has been described by Mr. Maufe [1] from the neighbourhood of Dunbar, where a number of necks are exposed on the foreshore. In size the latter vary from quite small orifices up to openings half a mile in diameter. Their included material is in the main a sandy tuff containing glass lapilli, blocks of amygdaloidal basalt and non-volcanic debris

[1] *Geology of East Lothian*, p. 90.

derived from the Calciferous Sandstone series and Old Red Sandstone. Occasionally, they are traversed by plugs and irregular masses of analcite-basalt. "Some of these necks pierce the summit of low anticlines or domes which are overlapped by the succeeding beds, thus proving that the folds in these cases are contemporaneous with the deposition of the sediments. In one example, the overlapping beds seem to cover over one end of the neck, so that these small vents are perhaps contemporaneous with the surrounding beds of the Cementstone series . . . Four of the small necks are situated on lines of fault occupied by dolerite dykes of the type which elsewhere in the country cut the Coal Measures, but in this locality it is merely possible to recognize that the dykes are all younger than the necks . . . *the main movements along the faults preceded the formation of the necks.*" Stating these results in different language it is obvious that we have here an actual occurrence of faults of intra-Carboniferous development. It is not unlikely that such fractures either may have resulted from igneous injection or were catastrophic effects attributable to some sudden transference of magmatic gases.

Without digressing at length into the possible field contingencies of igneous intrusive displacement, it is perhaps permissible to point out that as an interpretative instrument the suggestion may occasionally prove useful. Thus it might be expected, in an area which had been freely injected, that somewhat puzzling dispositions should exist. Faultings might be discovered seemingly of prior date to the emplacement of an adjacent intruded rock body: lines of disruption possibly passing into the material of the latter, but without evident introduction of discontinuity in the outcrop. At the same time there might conceivably occur deceptive evidence of posterior faulting, but this would be due to a process of block lifting, or tilting, and to the igneous rock emerging along an upthrust, or float-up, face. Dykes filling contiguous fault fissures it is also thought, might be a natural accompaniment of these features. One would, of course, be careful not to confound structural relationships of this order with effects resulting from an operation of the large-scale tectonic processes.

Some interesting economic questions arise in connexion with the geology of the Largo district. As has been said, the structure of the area is that of a large shallow syncline. The coals referred to by Landale—the Strathairly Coals—occupy stratigraphically what is known in Fifeshire as the "Capeldrae" position: that is to say they are intercalated in the Upper Limestone group. Below them must lie the Edge or Lower Coals, a valuable series of "metals" and including the famous Dumfermline Splint seam. Whether the latter coals are available here, and, if so, to what extent they have escaped destruction by igneous protrusion, could only be ascertained by deep boring. To the west of Largo the dip rolls over until at Thomsford Bridge the Levenseat Limestone is reached. The

Strathairly Coals, therefore, should again come into position here, and below them the Lower Coals. In the little ravine at Baldastard the rocks are inclined towards the north, but cannot extend far in that direction without either undergoing a reversal of dip or being faulted to the south, as at Teasses, just over a mile distant, the Hurlet Limestone and associated strata come to the surface. The north-easterly extension of the Largo centroclinal ranges over by Lathallan, where in 1896 a deep bore was put down in order to prove the minerals. A number of coal seams were passed through in the course of the operations, most of them thin but including one 4 feet in thickness. At a depth of 77 fathoms some thin limestones were pierced, perhaps indicating the horizon of the Index Limestone, while at higher levels there occurred a number of thick ash zones. It so happened that immediately beneath the surface soil a deposit of ash 120 feet in thickness was encountered. Sir Archibald Geikie thought this might be part of the superficial spread of volcanic detritus, which he believed to envelop the whole of this district. On the other hand it must be clearly stated that from the evidence of the bore Sir Archibald Geikie saw "no reason to doubt that true tuffs are intercalated among the Carboniferous series in the tract south of Lathallan". As at Largo and Thomsford, it is here probably the Lower Coals, in view of their economic possibilities, that might be deserving of further investigation.

No special reference has so far been made to the ash of the Largo foreshore. This, hitherto, has been regarded as forming part of the materials of one large neck, but such certainly cannot be the case. It can readily be seen to be naturally separable into two main areas, viz. that to the east, and that to the west of Johnston's Mill, a large sandy bay dividing them. Towards the south-west corner of this bay, especially during times of stream tide and at low water, fine red and dark ashes crop out, lying very flat or undulating and grading down without interruption into shales, sandy shales with plants and sandstones. These rocks dip to the east or north-east, and are cut off towards the north by the western area of agglomerate; the junction over part of the beach forming a distinct line. East, across the bay and apparently higher in the stratigraphic sequence just noted lies the eastern area of ash or agglomerate. The passage upwards into the latter is not quite regular, but probably is not more irregular than one might expect from a discharge of coarser detritus falling naturally upon a substratum of finely comminuted material such as the red ashes represent. In addition, the rocks are traversed at this part by frequent hitches and small faults which make the order of things perhaps somewhat more difficult to understand. The whole of this eastern tract of ash has clearly been folded along with the underlying strata, and it is this, above other considerations, which has introduced such disturbance as is here observable into the outcrops

of the ash layers. The latter, however, often show great regularity as, for example, where they wheel round a fine qua-qua-versal or dome in the midst of the area. The folding of these ashes affords a type of phenomenon quite different from anything to be seen in the eastern or inland necks, and the conclusion arrived at is that the evidence in favour of their being regarded as part of an interstratified zone is irresistible. It may now be of interest to quote from Sir Archibald Geikie's description of the pyroclastic material here displayed :—" It is a rock," he writes, " which repeats the characteristic features of the larger necks, such as those of Kincraig and Elie. Most of it is composed of the familiar dull green volcanic dust and gravel, with comparatively few large ejected blocks. Its stones are chiefly amygdaloidal or cellular basalts, which for the most part hardly exceed 6 inches in length. Worn crystals of orthoclase like those of Elie may be obtained from the eastern part of the mass." It will thus be seen that Sir Archibald Geikie could detect no essential difference between this interbedded material and that of the typical necks. Further investigation fails to reveal any point of distinction. Crystals of the so-called " orthoclase " seem indistinguishable from similar xenocrysts collected out of the tuffs and dykes to the east of Elie and from the necks at Kinkell on the north coast of the county. Wherever obtained in East Fife, cleavage flakes of this felspar, parallel to the basal plane, always show a greater index of refraction for transmitted polarized light, the vibration traces of which are approximately at right angles to the albite lamellæ, and a lesser index for the complementary position of extinction. Conoscopically examined, the interference figure suggests that the sections are parallel to the optical axial plane. Immersed in benzonitrile, $\mu = 1{\cdot}528$, and assuming the above orientation, α is less, and γ greater, than the refractive index of that medium for yellow light ; but when examined in blue light both indices are less than that of the liquid, while in white light colour fringes are produced. The angle between the $\alpha : \beta$ plane and the trace of (010) is 7 degrees. Professor Heddle believed the mineral to be sanidine, and thought that the crystals might have been derived from some disrupted trachytes, such as occur in the Garleton Hills in East Lothian. Subsequently the felspar has been regarded as soda-microcline, and possibly may be correctly so designated. Also blocks of basalt were sliced and ascertained to contain a little felspar, much glass, occasional analcite, and abundant purple pyroxene. One unique ejected fragment, however, of a paler, finely crystalline rock, proved upon microscopic examination to be a mugearite.

The western ash has not been investigated in sufficient detail to sanction more than a brief reference to it. The junction at Viewforth appears unmistakably to be a vent junction ; the strata just to the east of where Mr. Kirkby's marine band comes to the surface being sharply turned down against the volcanic rock. The

boundary is not straight, but sinuous, and is of the transgressive character that one generally associates with a neck. Further, the material to the east of this line is a typical neck aggregate with very large included blocks; proximity to some volcanic orifice being probably thus indicated. Among the debris may be noted variously disposed pieces of some pre-existent, well-bedded ash. The latter sometimes are of great size, and have not had their stratified structure destroyed. It is obvious that this vent was not opened until the basement members of the volcanic series referred to in the preceding pages had accumulated. It would be interesting to suppose that on the Largo foreshore there is a neck (the western ash) with part of the extruded material (the eastern ash) still preserved, but that must remain for further study.

The western ash is deserving of special note, for its large number of enclosed blocks of coarsely crystalline dolerite. These vary in size from quite small fragments up to masses that must weigh many tons. Many of them have been sliced, and on examination prove to be quartz-dolerites; frequently decomposed, but some fairly fresh and showing interstitial micropegmatite. The presence of these was noted by Mrs. Wallace, who also obtained samples from the neck at Ardross: they likewise have lately been obtained from the neck at St. Monans Church, with fresh hypersthene.

Hitherto, the quartz-dolerites have been regarded as of Permo-Carboniferous age. It will, however, immediately be seen, not only that such an opinion must be quite wrong, but that also some of these masses had been emplaced and were actually crystalline solids before their disruption by active volcanic forces in Lower Carboniferous times. Evidently the igneous history of the Carboniferous period is something less simple than yet conceived. Thus, there is a quartz-dolerite dyke cutting a vent 3 miles to the east of St. Andrews plainly affording an intersection of evidence. But there is good reason to believe that rocks of this type have as the result of intra-telluric processes been delivered at higher levels in the earth's crust upon more than one occasion in the course of geological time. In Forfarshire, for example, there is a series of quartz-enstatite-diabases carrying acid segregation veins with micropegmatite, and which probably are of Devonian age. And, in addition to the Carboniferous quartz-dolerites, Professor Jehu and Mr. Craig recently report a large number of similar dyke intrusions from the Outer Hebrides, which from preliminary work they are inclined to believe may have formed part of the volcanic cycle of early Tertiary times.

These notes may now be concluded with a restatement of their main thesis, which is that the necks of East Fife should be relegated to the Lower Carboniferous. Never previously have they been placed so far back in the time scale. But the history of their investigation is one in which their antiquity has been successively

heightened. Thus Professor Edward Forbes thought they might only have become extinct during Tertiary times, a suggestion with which Dr. Heddle subsequently professed himself in agreement. The first to assign the vents to the Permian appears to have been Sir Archibald Geikie, who, in addition to making the most profound contact with them as occurring in the field, brought to bear upon a synthesis of their natural history co-ordinative and imaginative faculties of quite exceptional order. What the present paper does is to cite, as the writer believes, substantial evidence for a transference of the necks back into the Carboniferous, thereby removing much of the uncertainty that hitherto has been associated with the question of their age. Formerly, as it were, we could discern across the waters of the sea of time the smoking conical summits, and the gleam from the craters, of these old Fife volcanoes; but always their lower slopes were obscured, as by a driving haar; we could attain no knowledge of the land out of which they grew. In the Largo district, however, the mists seem to retreat, our vision clears and expands, and the territory so long concealed becomes at last visible.

The Shell of *Cornulites*.

By F. A. Bather, M.A., D.Sc., F.R.S.

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THE Geological Department of the British Museum is much indebted to Dr. Cowper Reed for his careful description of the Girvan fossils which he assigns to *Cornulites* (Geol. Mag., Vol. LX, 1923, pp. 268–76). A slight correction, unfortunately, is necessary. Various specimens received from Mrs. Robert Gray as "Tentaculites" were registered in the Department under the numbers correctly quoted by Dr. Reed. He himself, in returning the specimens to us, pointed out, also correctly, that some of them were of quite different nature. He omitted, however, in some instances, to remove those numbers from the lists that he quoted. To prevent further confusion, the numbers to be cancelled are given below. At the same time, opportunity is taken to quote the number of the specimen that is hereby selected as the holotype of each new species. The numbers then remaining will denote the paratypes.

Cornulites girvanensis, Holotype, A. 2461, pl. xii, f. 1. A. 2453 (re-registered as E. 24714), is a fragment of the cirriferous pentamerous stem of a crinoid. A. 2454 (re-registered as E. 24715) is a stem-fragment, probably of the same species.

C. camregnanensis, Holotype, A. 2473, pl. xii, f. 4.

C. mullochensis, Holotype, A. 2468, pl. xii, f. 6. A. 2514 (re-registered as E. 24716) is the circular stem of a crinoid, with each fourth or fifth columnal projecting.

A. 2516 (re-registered as S. 1949) is probably a sponge.

C. shallochensis, Holotype, A. 2482, pl. xii, f. 8.
C. vinei, Holotype, A. 2464, pl. xii, f. 11.

Dr. Reed has told us the opinions of other writers on the distinction between *Cornulites* and *Tentaculites*, but it is not easy to gather his own opinion. Apparently he regards the shell of *Cornulites* as composed of a number of rings, as separate from each other as are the sections of a field telescope or the similarly imbricating columnals of certain cystids; while the shell of *Tentaculites* is,

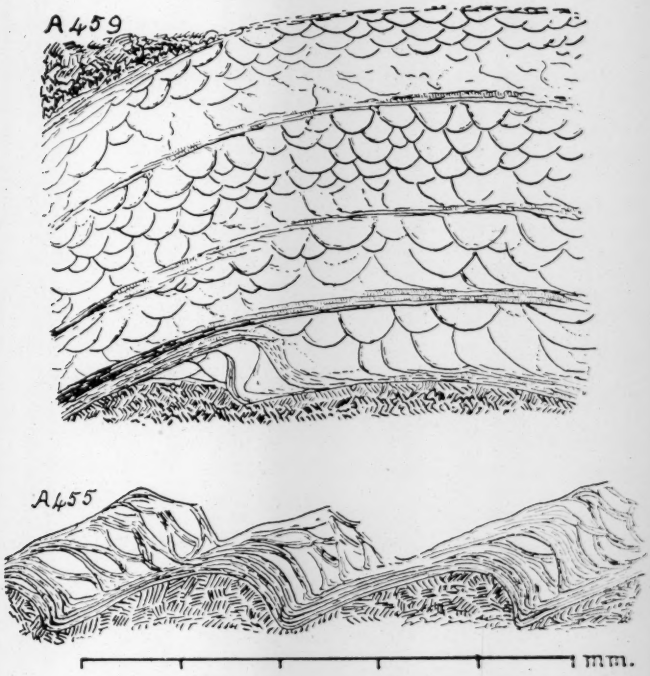

FIG. 1.—*Cornulites serpularius* Schlotheim.
A. 459. Transverse section across the wall at the larger end of a well-grown shell.
A. 455. Longitudinal section of the wall about half-way down a similar shell.
In both drawings the matrix filling the interior is represented on the lower side. The drawings are accurate, but slightly simplified.

for him, all of one piece. He then concludes that "the segmented nature of these shells appears sufficient to place them definitely as members of the *Annelida tubicola* and to separate them from the Pteropoda".

This is rather puzzling, for segmented tubes are certainly not characteristic of the Annelida tubicola, and one would naturally have used such a structure as an argument against that relationship. If, on the other hand, the tube of *Tentaculites* is not segmented

(and there is reason to believe that it is not), then that fact does not prove its Pteropod nature or prevent its ascription to the Annelids.

Actually, however, the tube of *Cornulites* does not consist of separate imbricating rings, but is a perfectly continuous structure. It is true that the phraseology of most writers has been regrettably ambiguous, but J. de C. Sowerby's figures 8 and 9 on plate xxvi of Murchison's "Silurian System" are clear enough on this point. Neither Salter nor any of the authors quoted by Dr. Reed gives a really good figure of the shell-structure. My own remarks are based on vertical and transverse sections of a specimen in the British Museum from the Wenlock Limestone, Dudley, identified as *Cornulites serpularius* Schlotheim and registered A. 455 (Fig. 1). The appearance in transverse section at a more advanced stage is shown in A. 459 (Fig. 1). It is clear from these sections that the animal threw off successive layers of cuticle, which sometimes were separated, perhaps by a secreted gas or liquid, to form the bubble-structure, but which were essentially continuous. They became stiffened by minute prisms of calcite, barely seen on the scale of the drawings, at right angles to their surface. In the fossils the spaces of the bubbles are filled by secondary crystalline calcite. The layers are occasionally separated by black lines, apparently of carbonized organic substance, and more rarely by thin films of mud that crept in through cracks. The constrictions and annulation are hardly distinguishable in the youngest stages.

The mechanism that produced the structure was, no doubt, a periodical shrinkage and sloughing of the outer hardened membrane; it may be compared with the shrinkage of the visceral cone in the cephalopods, and the resulting structures remind one of the sheaths ("endocones") in *Endoceras*. In *Tentaculites* similar sheaths are said to occur, but there the animal advanced in its shell as did the cephalopod, while here in *Cornulites* there is no evidence that the smaller end of the animal was ever retracted. At the larger end of an old shell (A. 459) the bubble-structure or vesicular tissue is so abundant as to remind one of that curious Ordovician fossil *Beatricea* (= *Aulacera*). This, as Professor C. Schuchert reminds us in the latest paper on the subject (*Amer. J. Sci.*, ser. 4, vol. 47, 1919, pp. 293–6) has been referred in turn to algæ, rugose corals, cephalopods, foraminifera, and stromatopores, but never to the annelida. Why not? If a *Cornulites* were to grow bigger and to develop irregular endocones as it retracted its smaller end, it would produce a skeleton extraordinarily like that of *Beatricea*. There is, however, this important difference: whereas the bubbles of *Cornulites* are concave outwards, resulting in irregular pitting of the slightly worn outer surface, those of *Beatricea* are convex outwards and produce on the outer surface raised papillæ, as noted by Parks (1910, p. 43). Those papillæ run in curved lines, as well shown in the British Museum specimen H. 1050.

These remarks are not meant to suggest that *Cornulites* was a mollusc or a hydractinian. But the precise zoological position of the animal, the cause of those constrictions in its body that produced the appearance of imbrication, the origin of the annulation and cellular structure, and the advantage to a fixed creature of this mode of strengthening the shell: all these are problems for future solution.

The Mechanism of Sedimentation Cycles.

By A. K. Wells, M.Sc., F.G.S., and S. W. Wooldridge, B.Sc., F.G.S.

THE publication of Dr. Stamp's *Introduction to Stratigraphy* has confirmed certain doubts we have for some time entertained concerning the mechanism which he believes to have been responsible for the cycles of sedimentation during the Eocene Period. When reading through the proofs we made known to him our doubts, but as the theory appears in an unmodified form in the book, we feel justified in reopening discussion of the subject.

It may be stated at the outset that, with reference to major cycles of sedimentation, there is no question as to the sequence of events nor to the type of earth-movement responsible for their production.[1] For example, there is general agreement that the occurrence of marine Carboniferous Limestone resting on O.R.S., is a case of marine transgression over a sinking land area, the movement being essentially one of depression. Just as definitely, the higher Coal Measures and Permian strata are the results of elevation of the area. These and kindred facts are stated and carefully explained in the textbook, and it is all the more surprising, therefore, that the similar sequences of strata on the smaller scale of the minor cycles of sedimentation should have received from the writer so different an explanation.

In the paper in which he introduced into this country the continental nomenclature and classification of the Eocene rocks,[2] Dr. Stamp traces the consequences of a sea "transgressing over a steadily sinking land", outlining the sequence of events and the nature of the deposits at various stages. But in his application of these principles to south-east England during Eocene times, the impression is clearly conveyed, although nowhere definitely stated, that the several marine transgressions resulted from periodic uplifts of the Weald. In the textbook, however, the theory is stated much more definitely. The question is asked: "What would be the effect of an uplift of part of the sea-floor, such as might result from the formation of an anticlinal fold?" Our answer to this question is very different from that of Dr. Stamp, and obviously depends upon the condition of the basin of deposition

[1] Marr, *Principles of Stratigraphical Geology*, 1905, pp. 118, 119.

[2] "On Cycles of Sedimentation, etc.": Geol. Mag., Vol. LVIII, 1921, p. 108.

—upon the nature of its shore-lines, and more particularly whether it was completely or only partially enclosed. Unfortunately, Dr. Stamp can be accused of inconsistency on this point, as, after stating that the Anglo-Gallic [1] basin was " a *partially enclosed* sea ", we are asked to picture an *enclosed* sea such as the Caspian or the Baltic of the present day. However, let us examine the results of uplift of part of the sea-floor in both of the examples cited.

In the case of the Baltic, uplift of the sea-floor in whole or in part could cause no redistribution of land and sea whatever until a barrier had been raised above sea-level and extended completely across the sea. Until this condition had been reached, displacement of the water by however great an uplift would result merely in an increased outflow through the channels connecting the Baltic with the North Sea, both sea-level and coast lines remaining constant throughout. Further uplift would now cause the water enclosed to the north of the barrier to transgress over the low-lying shores, but to the south of the barrier no such transgression would be possible.

As the Wealden anticline at no period of the Eocene formed a barrier completely enclosing the northern portion of the basin, the marine transgressions which undoubtedly did occur cannot have been the result of uplift of that fold, and, as we should expect, they are not restricted to any one portion of the basin.

Taking now the case of the completely enclosed basin, it will be agreed that any movement of uplift, however slight, would be reflected in a slight alteration of sea-level. If the upward movement is considerable, the result would undoubtedly be a transgression of the sea over the low-lying coastal areas. Now Dr. Stamp's answer to his own question is to the effect that uplift of the Weald would cause the marine waters to spread in all directions, and that " the history of the Eocene may be summarized as a repetition of such movements ". As we have shown above, this could happen with an enclosed basin. But was the Anglo-Gallic basin a Caspian ? Dr. Stamp has already said not, and it is generally agreed that during the marine periods at least there was communication with the outer sea, permitting migration into our area of part of the fauna of the Tethys. It appears, therefore, that at those periods when, according to the theory, the basin must have been totally enclosed, it was actually in communication with the outer ocean. If for the sake of argument we allow that the basin was enclosed during the " continental periods ", the easiest, and we believe the only way of bringing about communication with the ocean is by causing depression of the area, including the barrier between the two. No amount of uplift could ever bring about this result.

It thus appears that the theory is built upon an unsound premise, and we proceed to examine the correspondence of the suggested mechanism with some facts of Eocene stratigraphy.

[1] " Anglo-Gallic " is a contraction for " Anglo-Franco-Belgian ".

Dr. Stamp has clearly shown that the Woolwich Bottom Bed of the London District is co-eval with the uppermost zone of the French Lower Landenian. In both cases we have evidence of a marked extension of the sea, which in France carried marine conditions as far south as Paris, while in this country it gave rise to the overlap of the marine base of the Woolwich and Reading Series. If this extension were in the nature of a marginal overlap, caused by uplift of the Weald, it should clearly correspond with a retreat of the sea round the "Wealden Island". This is not the case. It has been shown that in Kent, on the flank of the Weald, the Woolwich Beds overlap the Thanet Sands just as they do in the other parts of the basin.[1] Thus there was at this time no elevation of the Weald, but rather a pronounced subsidence, which, since the Woolwich Beds are in turn overlapped by the Blackheath Beds, seems to have continued into Ypresian times.

It is further implied in Dr. Stamp's writings that the pebble bed which occurs at the top of the Thanet Sands owed its origin to a slight Wealden uplift which caused masses of pebbles to move down into the deeper parts of the basin. Uplift must, however, normally tend to lift littoral deposits beyond the reach of wave action. The Eocene pebble beds are more plausibly ascribed to the re-distribution of pebble beaches by wave action during a period of subsidence.

In several publications emphasis has been laid upon the wide extension of shallow water conditions towards the close of Landenian times. At this period the greater part of the basin was lagoonal or estuarine, with a restricted marine area towards the centre of the basin. In such circumstances "a slight earth movement would cause the sea to invade the whole area". We agree, provided the movement were one of depression. But Dr. Stamp, invoking the reverse movement, imagines that "uplift of the Weald caused the sea to rush in and occupy the whole of the Woolwich estuarine area", converting it into a sea. Now we submit that elevation of part of the sea-floor of this very shallow sea could have only one result—a further shallowing of an area which was already not much more than submerged. Surely it is obvious that elevation of the Weald, which at that time lay between the two estuarine areas and was possibly already an island, must have resulted in the extension of that island, and in the replacement of the estuarine Woolwich by the continental Reading facies. Further, is it not an unnecessary complication to introduce a widespread marine transgression by a movement of *uplift* when the spreading of these waters was accompanied by a *deepening* of the sea during London Clay times?

Turning now to the London Clay, we may note that its accumulation under conditions of subsidence has been generally recognized.

[1] C. E. N. Bromehead, *Proc. Geol. Assoc.*, vol. xxxiii, 1922, p. 325.

Prestwich [1] concluded from faunal studies that a depth of some 100 fathoms was reached before sedimentation redressed the balance. This figure can lay no claim to precise accuracy, but is probably not far wide of the mark. Making any estimate of the height and extent of the supposed Wealden Island, it seems inevitable that it must have been largely submerged during the period. It is true that the respective Ypresian faunas of the London and Hampshire basins are in many ways distinct, but we do not require an uplift of the Weald to account for this. We are asked to believe that an uplift had the surprising result of inundating the uplifted area, but this is quite impossible. It can scarcely be doubted that the Ypresian transgression was part of a regional negative movement quite independent of the uplift of the Weald.

It seems necessary also to call attention to the relation of the London Clay to the overlying Bagshot Beds. Over large areas the former passes up into the latter by the gradual incoming of sandy sediment. Similar passages from argillaceous to arenaceous beds are common in the stratigraphical record, e.g. in the Harlech Dome; the Maentwrog Beds bear such a relation to the Ffestiniog Beds. Such cases are normally interpreted as due to uplift, which, combined with rejuvenation of the river systems, brings the area in question within reach of sandy sediment. Dr. Stamp, however, correlates the Bagshot Sands and all similar continental portions of the various cycles with quiescent intervals when the uplift of the Weald had temporarily ceased and during which the margins of the basin were silted up with river-borne sediment. If this were the case, deep-water conditions should persist in the central parts of the basin, since there is no general elevation of the sea-floor. We find, however, that both in eastern Essex and in Belgium, the deep-water London Clay gives place in its upper parts to fine-grained marine sands which can have no conceivable connexion with silting-up of the marginal parts of the basin, but point rather to definite positive movement.

In view of the facts quoted, therefore, it seems reasonable to reverse Dr. Stamp's argument and to regard the Bagshot Sands as due to an uplift which terminated the Ypresian transgression—an uplift which may have included the Wealden area, but certainly affected a much wider region.

Dr. Stamp has recently extended the principle of cycles of sedimentation to the Oligocene Series.[2] In the absence of a statement to the contrary, one assumes that the same mechanism is meant to apply in this case also. It is to be observed, however, that the geographical conditions were now wholly different. Whatever was the nature of the Eocene basin, there can be no doubt that the Oligocene sea was not enclosed. The Hampshire and Paris

[1] "Geology of the London Basin": *Mem. Geol. Surv.*, vol. iv, 1872, p. 275; *Quart. Journ. Geol. Soc.*, vol. iii, 1847, p. 374.

[2] *Introduction to Stratigraphy*, 1923, p. 282.

regions formed merely the western termination of an extensive body of marine waters which covered Belgium, Denmark, North Germany, and South Russia. The Wealden region must have formed part of the northern shore of this sea, and renewed uplift of the area certainly could not have produced such a transgression as that which carried the Stampian marine fauna into the Hampshire and Paris basins.

We wish to state that we have no doubt as to the existence of the actual cycles. Broadly speaking, the necessary condition for the production of cycles of sedimentation is a comparatively rapid alternation of positive and negative movements. Such conditions have undoubtedly been realized many times during geological history. For example, the nature and extent of the various Middle Jurassic beds of the Yorkshire coast strongly recalls those of the Eocene strata, and investigations now in progress suggest the presence of cycles here also. We cannot at present account for the necessary recurrent movements. In the Eocene cycles we want precise information as to the behaviour of the Nummulitic Ocean of Southern Europe during early Tertiary times. It seems probable that the successive transgressions in North-West Europe were merely local expressions of more widespread movements affecting the whole of the Eocene Tethys, evidence for which must be sought in Southern Europe.

As regards the Wealden anticline, it would be foolish to deny that the early stages of its growth influenced Eocene sedimentation, but its influence was neither so paramount nor as far-reaching as is implied by Dr. Stamp's treatment. He pictures its evolution as a series of uplifts separated by quiescent pauses. As far as the London Basin is concerned, it seems more in accord with the facts to envisage a series of uplifts alternating with periods of slow collapse, possibly occasioned by a straining after stability following uplift upon too broad a base. The nature of the collapse is indicated by its history in later Tertiary times. Following upon the post-Diestian uplift, the northern flank of the Weald certainly had a greater extension than at present. Southern tributaries of the Pre-Glacial Thames then carried the Lower Greensand chert into elevated situations far to the north of the present Thames valley. The subsequent southward migration of the valley to its present position could not have taken place against the dip, and can plausibly be ascribed to collapse of the Weald flank. It is not appropriate to discuss the matter fully here, but there is much clear evidence tending to such a view. The point is mentioned as indicating the probable nature of the earlier stages of the anticlinal growth. In as far as the Weald had any connexion with the cycles, the relation seems to have been the converse of that suggested by Dr. Stamp. Periods of uplift corresponded to the continental phases of the cycles, while periods of collapse caused an advance of the sea up the flanks of the Weald.

In conclusion, although Dr. Stamp's works certainly embody ideas replete with interest and suggestion, we wish to advocate a divorce of the undoubted facts from a theory which seems to us totally inadequate to explain them.

The papers in which Dr. Stamp's suggestions are embodied include the following:—(1) "On Cycles of Sedimentation in the Eocene Strata of the Anglo-Franco-Belgian Basin": GEOL. MAG., Vol. LVIII, 1921, pp. 108, 146, and 194. (2) "On the Beds at the Base of the Ypresian in the Anglo-Franco-Belgian Basin": GEOL. MAG., Vol. LVII, 1920, p. 380. (3) "Sur les Couches de Bas de l'Yprésian dans le Bassin Anglo-Franco-Belge": *Ann. Soc. Géol. Nord*, vol. xlv, 1920. (4) *Introduction to Stratigraphy* (Murby), 1923, pp. 13, 267.

Nomenclature and Relations of the Lamprophyres.

By J. STANSFIELD.

THE alnoites form one of the rarest groups of dike rocks. Owing to their restricted distribution, they have remained comparatively little known, outside of the original alnoite of Alnö I., and a few North American occurrences, until the last few years. Recently, owing to discoveries in Canada (near Montreal), and near the Bohemian Mittelgebirge (in the Polzen valley), a great deal of interesting information regarding the alnoites has come to hand, which shows that the alnoites form a composite group of great interest; that the field relations of the alnoites indicate that absorption of limestone may have had an important effect in establishing the type of magma from which the alnoites are derived; and that absorption of limestone has undoubtedly given rise to a number of interesting rock types, which are to be regarded as branches of the main alnoitic stem. Most of these new rock types have been described by Scheumann (1),[1] from the Polzen district. Some have been found near Montreal, and have been described by Harvie (2), Bowen (3), Howard (4), and the writer (5). The description by the writer of a plutonic rock (okaite) from near Montreal, which is clearly related to the hypabyssal alnoite group, adds interest to a general view of this group of lamprophyre dikes, and suggests ideas which may be extended to the monchiquite, fourchite, and camptonite groups of dike rocks.

All of the alnoite group of dikes may be regarded as being derived from a parent plutonic magma of the general type of okaite (which is composed of melilite, biotite, and haüyne, as essential constituents; nepheline is present, in addition, in a nepheline-okaite).

From such a magma the earlier crystallizations are richer in MgO than the magma itself, and are characterized by the presence of olivine, augite, hornblende, and biotite. Most of the alnoites

[1] Figures in parentheses refer to Bibliography at end of paper.

show a predominance of these constituents, and so have a more highly magnesian composition than the parent magma, indicating in the writer's view, differentiation by fractionation. Reaction often takes place between these first formed ferro-magnesian minerals and the mother liquor, with which they are not in equilibrium, the final result being the formation of biotite as the sole representative of the ferro-magnesian group of minerals. In the case of the plutonic rock this result is clear. It is also seen in the case of some of the dike rocks (see below).

All of the alnoites may be regarded as characterized by ferro-magnesian minerals and melilite. Glass may be present or absent. Olivine is an essential constituent of a typical alnoite, and biotite is never absent. Augite is commonly present, hornblende sometimes. The absence of augite and hornblende, in view of the reactions mentioned above, does not appear to be a sufficiently important reason for the establishment of new rock names for such varieties. In the low-magnesian varieties biotite is the only ferro-magnesian mineral present (biotite-melilite rock of Isle Cadieux and bergalite of Kaiserstuhl). These are to be regarded as offshoots of the main alnoitic types, and due to the crystallization of the mother liquor in which the reactions mentioned above have been completed, with the elimination of olivine, augite, and hornblende. It is suggested that the prefix "biotite-" to the rock name in this group of rocks should connote the existence of biotite as the sole ferro-magnesian constituent. The biotite-melilite rock of Isle Cadieux could be named "biotite-alnoite" and bergalite could be called "biotite-polzenite" (see below).

The recent recognition (1, 3) of monticellite as an essential constituent of some alnoites has an important bearing upon the origin of alnoitic magmas by the assimilation of limestone, and the practice adopted by Bowen, of prefixing "monticellite-" to the rock name appears to be preferable to coining new names for rocks characterized by this mineral. The case appears to be different with the appearance of nepheline, a member of the haüyne group, and calcite as products of the crystallization of the alnoite magma. Each of the rock types characterized by the introduction of each of these minerals appears to be worthy of a distinctive name, to which the prefixes "biotite-" and "monticellite-" may be apposed in accordance with what has been written above.

Alnoite containing nepheline has been described by Harvie from Isle Bizard and La Trappe. The name BIZARDITE is suggested to designate a nepheline-bearing alnoite. The name MONTICELLITE-BIZARDITE could be applied to such a rock, containing monticellite, should one be discovered, at a later date. The introduction of a member of the haüyne group to a nepheline-bearing alnoite gives rise to a type to which the general name POLZENITE has been given. It is suggested that this name be retained to designate this subgroup, the name modlibovite being dropped, as synonymous with

polzenite. MONTICELLITE-POLZENITE would connote the monticellite-bearing member of the sub-group, and the synonymous vesecite could be dropped.

The appearance of calcite of magmatic origin in important amount would give rise to calcite-rich-alnoites, -bizardites, and -polzenites, each of which would be deserving of a distinctive name, if, and when they are discovered. A calcite-rich polzenite has been described by Scheumann under the name of LUHITE.

The following schematic table indicates the relations of the various members of the alnoite group, as recognized to date. It is suggested that they may all be derived from an okaitic magma. Relations between members of this group and members of the monchiquites, fourchites, and camptonites are suggested by the appendages to the table.

	F + M.	F + M + N.	F + M + N + H.	F + M + N + H + C.
With OLIVINE.	ALNOITE.	BIZARDITE.	POLZENITE (Modlibovite).	LUHITE.
	MONTICELLITE-ALNOITE.	[MONTICELLITE-BIZARDITE.]	MONTICELLITE-POLZENITE (Vesecite).	[MONTICELLITE-LUHITE.]
	BIOTITE-ALNOITE.*	[BIOTITE-BIZARDITE.]*	BIOTITE-POLZENITE (Bergalite).*	[BIOTITE-LUHITE.]*
	F + G.	F + G + N or A.	F + G + N or A + H.	
	MONCHIQUITE.	ANALCIME-MONCHIQUITE. NEPHELINE-MONCHIQUITE.	HAÜYNE-MONCHIQUITE (Wesselite).	
Without OLIVINE.	F(+P) + G.	F(+P) + G + N.	F(+P) + G + N + H.	
	FOURCHITE.	NEPHELINE-FOURCHITE.	HAÜYNE-FOURCHITE.	
	F + P.	F + P + N.	F + P + H.	
	CAMPTONITE.	NEPHELINE-CAMPTONITE.	HAÜYNE-CAMPTONITE.	* Without olivine.
	B + P.			
	KERSANTITE.			

F = ferro-magnesian minerals, M = melilite, N = nepheline, H = a member of the sodalite-haüyne group, C = calcite, G = glass, A = analcime, P = plagioclase, B = biotite. Synonyms in round brackets, types not yet described in square brackets.

Monchiquites.—Analyses of monchiquites and alnoites show that, in many cases, these two dike types are identical in composition, the alnoites being holocrystalline (as a rule), as a result of slower cooling, and the monchiquites containing a glassy base, as a result of quicker cooling. Though there is not known a diversified series

of monchiquites, as in the case of the alnoites, yet there are two well-marked groups, those characterized by a brownish glass only, and those characterized by a brown glass and analcime, or analcime alone. It is suggested, elsewhere (5), that the brownish glass of monchiquites may have a composition identical with that of melilite, this group of monchiquites corresponding with the alnoites (*sensu stricto*), while those monchiquites which have an analcime base in addition correspond to the bizardites. The nepheline-monchiquite "bekinite" (Brögger) corresponds schematically with bizardite, and the haüyne-monchiquite, wesselite, to polzenite. It is doubtful whether any monchiquites characterized by magmatic calcite are known. The calcite and zeolites often found in these rocks appear to be referable to post-magmatic hydro-thermal action.

The group just discussed forms a series of soda-lamprophyres, in which melilite, nepheline, haüyne, and plagioclase are minerals indicating the excess of soda over potash. The potash series of lamprophyres, in which orthoclase and abundance of biotite form the expression of excess of potash over soda, is not so complex a group as that of the soda-lamprophyres. Nepheline appears in the ultra-basic end of the potash-lamprophyre series. The following table shows the parallelism of this series and the soda series :—

(With olivine)	. .	DAMKJERNITE . .	F + N + C + O.
(Without olivine) .		SANNAITE. . . .	Ditto.
		VOGESITE . . .	F + O.
		MINETTE	B + O.

B = Biotite, O = Orthoclase.

The division between the two groups is not hard and fast, as an excess of potash over soda may occur among the members of the soda lamprophyres.

PETROLOGICAL NOMENCLATURE.

Bowen (6) has recently given voice to a sentiment long held by some workers in, and many generations of students of, the science of petrology, with regard to the endless multiplicity of rock names which continue to be introduced, when already well-known names may be at hand for use. The writer is in strong sympathy with this sentiment, yet feels that it is important not to depart from the well-established principles upon which rock names have been based.

A rock name is not applied to something with a definite chemical composition, or even to something with a definite mineralogical composition, as, for example, the term "granite". There are often gradations between one rock type and another, as all petrologists know. So it is impossible for the petrologist to use hard and fast, well-defined, quantitative terms, such as the chemist may use in connexion with the nomenclature of chemistry. Most of the rock types have been known for a long time, and any new rock described usually falls into place in the well-known scheme of

nomenclature. Any special feature attracts attention by a designation such as: "nepheline-syenite, (Foya type)," which conveys a definite impression to the petrologist.

Among the alnoite group some recently described rock types had no ready-made names awaiting their use, while according to the principles upon which the common rock names have been based, they are fully worthy of receiving names, which will quickly convey definite impressions, just as the names "troctolite", "theralite", and "trachyte" convey impressions. In the naming of these alnoitic rocks some synonyms have crept in, but that is not a good reason for condemning the use of all the new names. Indeed, some of them fill a definite place in the nomenclature of the science, where they will doubtless stay.

It is important to have a short name by which reference to a rock may be made. The single word of a rock name may involve the conceptions included in a long dissertation by some author, and its use is convenient in writing and discussion, for other authors, who may have slightly different views to put forward. An instance of this is Scheumann's (1) use of the term "Cadieux-gestein" in referring to the biotite-melilite rock of Isle Cadieux.

It is also important not to avoid the introduction of a new rock name, if there is not one already available. It is far better to employ a new name, which may be dropped, later, perhaps, in favour of some better or more useful name, than to apply an already well-known name to a rock which it does not fit. The application of the name camptonite to a rock containing melilite should be avoided. The extension of the use of names should be done carefully, so as to avoid such an impossibility as the term "nepheline-aplite". Aplite means something clearly and well known, and the association of nepheline with such a rock is never expected by the petrologist.

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REVIEWS.

DIE HEGAU-VULKANE. By HANS RECK. pp: 248, with 18 plates and 23 text-figures. Berlin: Borntraeger, 1923.

THE distinctive types of lavas in this South German volcanic district—viz. nepheline-melilite-basalts and nosean-phonolites—are familiar to most petrologists, but the vulcanology of the Hegau is less known than that of the neighbouring districts, the Kaiserstuhl and the Swabian Alb. In the contribution now before us the author attempts a study of the mechanism of vulcanicity on the same lines which he has already followed in Iceland. Although in this small area of long-extinct activity the data are not always free from ambiguity, the conclusions reached seem to be consistent and plausible.

Volcanic activity was initiated in the Hegau in later Miocene (Sarmatian) times, and came to an end in the older Pliocene. The sequence of events was different in the western and eastern parts of the area. In the former the volcanic rocks are exclusively of the nature of "basalts"—the name which, unhappily, the author employs throughout to designate rocks which in fact are characterized by nepheline and melilite. According to Deecke's view, the several basalt hills represent relics of spreading flows, the sources of which are not identified, but Reck makes each one the site of a distinct volcano. The arguments for this interpretation are given at length, but it is admitted that in no instance has erosion exposed the actual duct of the volcano. The successive stages of development distinguished in the western tract are set forth: (1) Formation of explosion-craters, with emission of gases and production of tuffs, at first mingled with much non-igneous material. The Wannenberg is an embryo-volcano in which activity has been arrested in the initial stage, with only gaseous products. (2) In all other instances a greater or less ring of tuff, with a low cone, has been built up about the orifice. (3) A pause permitted the loose ashes to become consolidated: meanwhile, differentiation was in progress in the magma-reservoir. (4) Local subsidence occurred beneath the old craters, indicated by a certain sagging inward. (5) Renewed activity took the form of a tranquil uprise of basaltic magma at the old centres, filling the crater but not in general extending beyond it.

The eastern part of the area differs notably from the western in the more extensive deposits of tuff and in the occurrence of plugs of phonolite: (1) Eruption of tuffs, essentially basaltic, constituted the earliest phase, and was succeeded by (2) subsidence and the deposition of fresh-water limestone towards the northern border. (3) Upheaval followed and renewed eruption of bedded tuffs. (4) Restriction of activity to local centres and formation

of tuff-volcanoes. (5) A pause, followed by (6) the uprise of a phonolitic magma in the form of a number of volcanic plugs.

The author discusses at length the relation of the several volcanic episodes to the tectonics of the area, but his exposition is too detailed to admit of a brief recapitulation. The memoir concludes with an appendix on the petrographical, and especially the chemical, characters of the volcanic rocks.

A. H.

Flore foliaire Pliocène des argiles de Reuver et des gisements synchroniques voisins (Limbourg Hollandais). By L. Laurent and P. Marty. Mededeelingen van 's Rijks geologischen Dienst. Ser. B., No. 1. Leiden, 1923.

IN this well-written and admirably produced Memoir the authors give the results of their thorough examination of fossil leaves collected, for the most part, at Reuver in Holland, on the Dutch-Prussian border. It was from this and neighbouring localities that Mr. and Mrs. Reid described a large collection of seeds in 1917.

During the Pliocene period, before the existence of the Straits of Dover, the North Sea was represented by a Gulf of the Arctic Ocean, and it is from the sediments of deltas accumulated in that Gulf that the records of the Reuverian flora have been obtained.

The plants are assigned to the earlier part of the Pliocene period.

A concise summary of geological data is followed by an excellent and adequately illustrated description of the species, which are arranged in three lists: the first list includes seventeen "good species"; in the second list are eight "espèces documentaires"; and in the third six species of doubtful value. It is, perhaps, a little rash to include *Pinus silvestris* and *Picea excelsa* in the first category. Leaves of deciduous trees form by far the greater part of the material.

The method of treatment deserves special praise.

It is the custom of many botanists who have not given close attention to the comparative study of leaf-form and venation to look with the utmost suspicion on attempts to identify flowering plants from impressions of the foliage. An examination of the methods adopted by the authors and of the evidence on which the conclusions are based can hardly fail to convince even the most sceptical that there is much trustworthy information to be obtained from a collection of Angiospermous leaves.

An interesting statement is made by the authors on their treatment of fossil plants—to them a fossil species is a concept very different from the species of botanists concerned only with recent plants: they adopt a synthetic rather than an analytical method and take account of the range of variation in leaf-form that is illustrated by a single tree. They do not multiply species without good reason, and their treatment of fossils is based on an intimate

acquaintance with recent plants. Three groups of plants are recognized in the Reuverian flora: plants which are still indigenous in north temperate Europe, e.g. Willows, Poplars, the Oak; a group of more southern types still living in Europe, e.g. an Alder, the sweet Chestnut, an Arbutus; and species now confined to the Orient or to America. The admixture of species suggests that Reuver is near the southern limit of the northern plants. A similar association is now found 10 to 15 degrees further south.

A comparison of the lists drawn up by Mr. and Mrs. Reid and by Laurent and Marty reveals many differences, but some of these on analysis are found to be rather apparent than real. The views of Mrs. Reid on plant migrations are criticized at length. The floras of temperate European countries during the Tertiary period were characterized by a mixture of geographical types: plants wandered south in consequence of the progressive lowering of temperature, and species that are now unrepresented in Europe existed there in the Tertiary period. The vegetation which has since become established in our regions formerly occupied territory between the North Pole and the Arctic Circle. The conclusion is that the forest belt which stretched across Europe in Miocene times—including, in addition to plants that are still indigenous, an American and an Asiatic element—still existed in early Pliocene days. Little by little this belt of vegetation was transformed into the present floras of Europe by the progressive elimination of types that now inhabit widely separated geographical areas. As the climate became colder in the Pliocene period the forest belt gradually retreated further south, and in its retreat encountered obstacles. Mrs. Reid considers the chain of the Alps as the most efficient barrier; M. Laurent and M. Marty make out a strong case against this view and in favour of regarding the Mediterranean depression as the chief obstacle to further progress. The floral elements that are now characteristic of western Europe never left that region: the Mediterranean flora, its migration to the south blocked by the sea, survived in favoured localities during the Glacial period and afterwards spread over a wider area. The effect of the Glacial period was to break up the Tertiary belt of vegetation into its diverse elements. The floras of to-day represent the fragmentary relics of the richer associations of the Tertiary age.

A. C. S.

REPORT ON THE CUPRIFEROUS DEPOSITS OF CYPRUS. By Professor C. G. CULLIS and A. BROUGHTON EDGE. pp. 48, with 5 plates. Published by the Crown Agents for the Colonies, London, 1922. Price 20*s*.

THIS interesting though extremely expensive report is the result of a mission to Cyprus, at the request of the Secretary for the Colonies, to investigate the possibilities of copper mining

in that island, which is known to have yielded copper in Roman and probably in Phoenician times. A brief but very clear account is given of the geology of Cyprus, illustrated by a large coloured map. The oldest sediments exposed, the Trypanian series, forming the axis of the Kyrenian Mountains, are believed to be Cretaceous. These are followed without apparent break by the Lapithos beds, probably Eocene. Then comes an unconformity overlain by the Kythrean series of Upper Eocene or Oligocene age. The next succeeding Idalian series of Miocene age occupies nearly half the island, and is largely of a chalky character, with marl and gypsum at the base and shelly or coralline limestones above. The Pliocene and Pleistocene formations lie horizontally on the edges of the older formations, but are not of much interest. They yield some good building stones and valuable deposits of salt from the lakes of Larnaka and Limassol.

Igneous rocks are important, including both lavas and intrusions. Most of them are basic or ultrabasic; of the plutonic types, gabbro, peridotite, and serpentine are the commonest, and a record of syenite seems rather doubtful. "Diabase" is confined to the Troödos range, and sometimes carries copper. But the largest deposits of copper ore occur in a very peculiar and unusual manner at the contact of pillow lavas with the marls at the base of the overlying Idalian, and form large flat lenticles, which often have only narrow outcrops on steep slopes. The authors conclude that the lavas welled up through fissures in the diabase during the deposition of the marls, parts of which are converted to umber by solfataric vapours. The ore-bodies lie on the igneous side of the contact. The ore consists of cupriferous pyrite, rarely with visible chalcopyrite, and in places, as at Skouriotissa, is of very high grade, running to 50 per cent sulphur and 2 to 2·5 per cent copper. Slight enrichment occurs here and there, bringing the copper up to 3, 4, or even 5 per cent, but the flat lie of the ore-bodies is not favourable to this process on a large scale. Low-grade disseminations also exist. The deposition of the ore is attributed to the checking of metalliferous emanations by the impervious marl, leading to replacement of the material of the lavas. At Skouriotissa, discovered in 1914, it is considered that 6,000,000 tons of high-grade ore, equal to Spanish pyrites in quality, have been proved. As to other prospects the authors are very cautious in their predictions, but they suggest that rich deposits might be found by systematic exploration by modern methods. Some of the large already-known disseminations might perhaps be worked by some leaching process, though too low-grade for direct mining under present conditions.

R. H. R.

ACROSS THE GREAT CRATERLAND TO THE CONGO. By T. A. BARNS, with an Introduction by J. W. GREGORY, F.R.S. pp. 276, with 82 figures and 2 maps. London: Ernest Benn, Ltd., 1923. Price 25*s*.

THIS pleasantly written account of an adventurous journey in Central Africa, undertaken mainly with an entomological object, contains a considerable amount of matter of interest to geologists, especially a graphic account of that remarkable region, hitherto mainly exploited by Germans, known as the Highlands of the Great Craters. Here is found what is probably the world's greatest crater, Ngorongoro, in the Engotiek district, some twelve by eleven miles in diameter, and surrounded by steep walls 1,700 to 2,000 feet high, with a lake 4 miles long on its floor. This crater and others like it, are due, according to Professor Gregory, mainly to subsidence; they occur in the down-sunken trough of the Eyasi Rift Valley, and are apparently of Oligocene age, or thereabouts. There are likewise in the same region a number of finely-formed volcanic cones of more normal type, such as Oldonyo-lengai, which is covered with a mysterious white coating, possibly due to some salt of soda.

The author gives a graphic account of the scenery, flora and fauna of the region traversed, and incidentally creates a very favourable impression of the activity and competence of the administration of the great Belgian colonies of Central Africa.

THE AUSTRAL RHYNCHONELLACEA OF THE "NIGRICANS SERIES", WITH A SPECIAL DESCRIPTION OF THE NEW GENUS TEGULORHYNCHIA. By FREDERICK CHAPMAN, A.L.S., and IRENE CRESPIN, B.A. Proc. Royal Soc. of Victoria. Vol. xxxv, part 2, pp. 170–93, plates xi, xii, xiii. 1923.

THE Cainozoic Rhynchonellidæ of the Australian "*Hemithyesis Nigricans*" series have been studied by Chapman and Crespin, who find that the peculiarities of the group necessitate a new generic name, *Tegulorhynchia*, having for genotype *Rhynchonella squamosa*, Hutton.

CORRESPONDENCE.

THE AGE OF THE HIRNANT BEDS.

SIR,—In his eagerness to claim the Hirnant Beds as Ordovician, Professor Jones has not stated the case completely. Whilst freely willing to admit that the structural details of the beds at Bwlch y groes are more complicated than my rough sketch-map indicated, the chief object of my note was to record the fact of the occurrence of beds containing *Dimorphograptus* overlying the *Phacops mucronatus* beds; the most convincing evidence was in a small exposure west of the road, where we found the *Dimorphograptus*

in a band about 5 inches vertically above mudstones containing *P. mucronatus* without any sign of discordance. These mudstones I believed to be the Moel-y-Ddinas beds of the Hirnant area. His statement, also, that the *P. mucronatus* fauna occurs 2,400 feet down in the Ordovician in Central Wales is most misleading: he should surely have made it clear that they are there in their usual position above the zone of *Dicellograptus anceps*, the highest Ordovician graptolite zone. It will probably be useful in future to note whether the fossil referred to *P. mucronatus* is the earlier mutation "*eucentra*" or "*mucronatus*" s.s. which seems to range higher, though both are seen side by side in the beds at Torver, near Coniston. Moreover, with regard to the graptolite shales of that area, Professor Jones knows as well as I do, that *Monog. atavus* is, for a graptolite, a long-ranged species, occurring in all three zones of *M. atavus*, *M. acinaces*, and *M. cyphus*, and being really more abundant in the two last named; its importance being that it is the earliest of all the *Monograpti* to make its appearance, and for some time is the *only* representative of that genus; now, as I p inted out to Professor Jones on the ground, *M. atavus* occurs in the Coniston district associated with another *Monograptus* which has not the leptograptid type of cell characteristic of *M. atavus*, but the simple cell of *M. cyphus*, and the assemblage of graptolites there is to me indicative of a higher horizon than that of the zone of *M. atavus*; I have not yet seen a graptolite fauna from that district indicating a lower horizon within the Valentian. Professor Jones is mistaken in thinking that *Cephalograptus acuminatus* has been found there. Professors Marr and Nicholson record it only from Browgill and note the occurrence of the *Atrypa flexuosa* zone in the Coniston district which, though correlated with the zone of *C. acuminatus*, has not yielded *C. acuminatus*.

I sincerely hope that some fresh definite evidence may be forthcoming to clear up this vexed question, which is complicated by the possibility of the Hirnant fauna being a facies fauna; hence the most convincing solution will be to find its equivalents in other districts. It is not so much the *vertical* succession that is needed as the knowledge of the age of the beds into which it passes *laterally*, especially if these be graptolite shales.

GERTRUDE L. ELLES.

SEDGWICK MUSEUM, CAMBRIDGE.
November, 1923.

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